

**Groundwater Discipline Report
Geology and Groundwater Sections
Lone Star Pit/Maury Island
King County, Washington**

1.0 PROJECT DESCRIPTION

The 235-acre site proposed for continued mining activities is located in portions of Sections 28 and 29, Township 22N, Range 3E, on the eastern edge of Maury Island next to Vashon Island and along the East Passage.

The King County Comprehensive Plan designates the property as a mining site and Lone Star Northwest is currently permitted to extract sand and gravel from the site. For the past 20 years, the site has been mined at relatively low levels to supply local markets on Vashon and Maury Islands. Off-site barge deliveries have occurred in the past.

Lone Star Northwest has plans to significantly increase mining at the site and to barge materials off the site using the existing dock. Lone Star Northwest proposes to increase its production rate at Maury Island from roughly 10,000 tons per year to up to 7.5 million tons per year (or 5.5 million cubic yards). This will result in cuts on the site of up to 300 feet in height. Locally, some overburden soils consisting of till are present. The till soils will be stockpiled and used during site reclamation activities.

Once an area is mined out and ready for permanent reclamation, slopes would be regraded to gradients less than two feet horizontal and one foot vertical, except where steeper slopes are necessary to match the existing topography. No fill would be used for reclamation slopes. The final exposed slopes would consist of cuts into native soils. Fifteen-foot wide horizontal benches will be placed in the finished cut slopes for every 100 feet of vertical relief to reduce surface water runoff. The 15-foot wide benches would be backsloped slightly into the hillside and laterally sloped to encourage gravity flow.

Alternatives being considered in the current Environmental Impact Statement (EIS) are the proposed action described above, two variations of the proposed action with lower extraction rates, and a no action alternative. The first alternative would be similar to the proposed action discussed above. Under alternative one, the annual production rate would be on the order of 5.7 million tons per year. Under the second alternative, the production rate would be on the order of three million tons per year. The no action alternative as defined in Chapter One of the DEIS would be the continued extraction of sand and gravel at existing rates for use on the Vashon/Maury Island markets only. The production rate for the no action alternative would be up to 20,000 tons per year.

2.0 PRIOR REPORTS BY OTHERS

We have reviewed prior reports by others for both the Lone Star Site and the Vashon/Maury Island area. These reports are listed in the references attached to this report in Appendix A. The nomenclature used in this report is generally consistent with the descriptions used in the Vashon/Maury Island Water Resources Study (Carr, 1983) and the Vashon/Maury Island Groundwater Management Plan (Vashon/Maury Island Ground Water Advisory Committee, 1998). The conceptual stratigraphic model used in the Carr report corresponds well with the conditions that exist at the Lone Star site. In addition, the hydrostratigraphic classifications used in the Management Plan are useful in discussing specific groundwater sources in the vicinity of the site. Both classification systems are used in this report. We referred to the United States Geologic Survey geologic map of the Vashon and Maury Islands (Booth, 1991), as well.

This report is generally consistent with the overall conclusions of prior studies by Carr and Booth. However, these prior studies were exercises that covered the entire area of Vashon and Maury Island. For this review of geologic and hydrogeologic conditions, we have focussed on Maury Island and have had access to additional well logs not used by the prior authors. In addition, significant new site specific explorations by Associated Earth Sciences, Inc. (AESI) are available. Hence, while the discussion in this report is consistent with prior studies, it is not identical.

3.0 SITE CONDITIONS

3.1 Surface

The project site is located on the eastern side of Maury Island in King County, Washington. The approximate location of the site is shown on the Vicinity Maps, Figures 1 and 2. Figure 2 shows the topography in the vicinity of the site. The existing site conditions and topography are shown on Figure 3.

In general, the site consists of a broad upland glacial plateau bounded by wave cut bluff along the eastern edge of the site. The native predevelopment topography consisted of a broad gentle slope towards the west. The development of the eastern portion of the site has resulted in a large excavation where up to 250 feet of material has been removed.

A conveyor belt system and barge loading dock are located in the floor of the existing pit. The existing pit covers an area of 40 acres of disturbed area, of which 9 acres are currently being mined. No formal reclamation process appears to have been performed. Inactive mined out areas are covered by a discontinuous cover of brush and grasses.

The portion of the site that has not been modified by borrow pit activities is covered by a typical second growth forest consisting of madrone and Douglas fir trees. Native underbrush provides a continuous groundcover in the forested area. A well used foot path marks of the boundary of the site in the forested area. A network of smaller paths provides access across some portions of the forested part of the site.

Two unpaved roads that lead off of SW 260th Street along the northern margin of the site provide road access. One road enters the site near the northwestern property corner and provides access to the upper portion of the site. The second road enters the site near the northeastern property corner and provides access to the lower part of the site, including the existing dock.

No surface water features were noted on the site. Erosion channels exist along the roadways. The erosion features dissipate once the native undisturbed areas of the site are present or the more permeable sands of the existing pit are present. No evidence of creeks or seasonal water bodies was present on the uplands or within the pit area on the site. Persistent seepage is present along the beach south and immediately north of the existing dock. The seepage emanates from the toe of the slope along the high tide line. However, no seepage was noted on any of the slopes above the beach level or within the modified slopes of the borrow pit.

The bluff face has an overall height on the order of 200 to 300 feet in height. The slope is covered by native growth except at the immediate location of the conveyer system and dock. There is evidence of localized shallow sloughing along the bluff. The toe of the bluff is exposed to wave erosion. With the exception of some rough shore protection at the dock, no existing bulkheads are present to prevent wave erosion on the site.

The only evidence of prior development noted on the site were some old foundations located in the base of the eastern ravine along the beach and a possible old foundation on the upland area near the northeast corner of the site.

The site is bordered by lands in use as low-density residential property and forest areas. Clusters of higher density single-family residences are present both northeast of the site at the Gold Beach area, and southwest of the site at the Shore Acres area.

3.2 Geology

3.2.1 Site Geologic Conditions

The site is underlain by a series of glacial and interglacial geologic units. The youngest geologic unit currently mapped on the site is a discontinuous layer of Vashon lodgment till. It is possible that there are local discontinuous pockets of recessional sands and gravel above the till in areas of the site. The distribution of the till is shown on Figure 4. This varies from the mapping of the Maury Island by Booth (1990). The mapping done by Booth was a regional effort. The map on Figure 4 is based on site specific observations by Terra Associates, Inc., and subsurface information developed by AESI. It is common for such variations to exist between regional mapping efforts and site specific focused mapping.

The Vashon till was deposited at the base of the Vashon age glacier that occupied the Puget Sound Basin about 13,000 to 16,000 years ago. This soil was deposited beneath the moving ice. Till consists of a heterogeneous mixture of clay to boulder sized materials. While in some areas of Puget Sound the till mantle consists of a relatively thick continuous soil unit, on the Lone Star site the till is relatively thin and is absent in many areas.

The thickness of the till exposed in explorations on-site by AESI varies from less than 1 foot to more than 11 feet. The thickest till segment was noted in AESI EP-2 along the top of the sea bluff in the southern portion of the site. At all of the other locations, the thickness of the till was a maximum of five feet. The permeability of till is commonly considered to be low. However, on this site, the thinner areas of till observed by Terra Associates will exhibit a moderate permeability. This is due to the lack of a cemented consolidated structure noted in the thinner exposures of the till soils observed by Terra Associates.

The next youngest geologic unit present on the site is the Vashon Advance Outwash. These are the soils that will be mined. The advance outwash soils were deposited by melt water streams and rivers that flowed off of the glacial ice as it advanced into Puget Sound from Canada approximately 16,000 years ago. These soils grade from fine sand near the base of the deposit to a coarser sand and gravel near the top of the geologic column. This is the condition that would be expected where the ice advanced closer to the present location of Maury Island. Within the advance sands, there are localized deposits of siltier soils that represent localized ponds on the aggrading alluvial front that precedes the actual glacial ice. Advance outwash soils will exhibit a range of permeabilities from high to moderate. In general, the higher permeabilities will be in the upper portions of the deposit where the coarser sands and gravels are present. Local areas of lower permeability will exist within the advance sand deposits.

The oldest geologic unit encountered in the explorations is what is believed to be the Olympia Formation, which was encountered in the deeper explorations. These older soils were encountered in the lower portions of Observation Wells OBW-1, OBW-2, OBW-5, OBW-7, and OBW-8. The Olympia Formation was deposited in lacustrine and alluvial environments in a nonglacial period that may have been similar to today's climate. In general, this deposit, as encountered on the Lone Star site, consisted of a fine sand with occasional wood fragments. This deposit is believed to grade upwards into the advance sand unit.

No significant silt or clay aquitard was identified in the borings on-site by AESI. This is a departure from the common stratigraphic conditions found in the central Puget Sound Basin. Typically, a lacustrine silt unit is present beneath the advance sand outwash deposit. This lacustrine silt body is called the Quaternary Transition Beds in the current nomenclature. These silt beds commonly form a significant aquitard that perches the groundwater within the advance sands. The transition beds are the aquitard that commonly separates the Principal Aquifer and Deep Aquifer discussed in Section 3.4 of this report.

3.2.2 Regional Geologic Conditions

Regional geologic conditions are shown on Figures 10 and 11. These geologic sections have been drawn based on the well logs presented in Appendix B. These well logs are from files at the Washington State Department of Ecology (Ecology). The locations of the wells are shown on Figure 9. Logs of the Sandy Shores and Gold Beach wells come from Washington State Health Department files. It should be noted that water well logs are logged by a variety of drillers using nonstandard terminology. The cross sections are based on our local experience in the Puget Sound basin.

As can be seen on the generalized cross sections, Figures 10 and 11, the site is located near the center of a subsurface basin filled with advance outwash. Soils with lower permeability appear to be present north, west, and

south of the subject site. The groundwater gradients shown on Figure 5 support this conclusion. A review of the text for the Booth map indicates that his data suggests the advance sands extended beneath sea level in the vicinity of the site extending northwesterly through Dockton. A review, for this study, of additional well logs in the Dockton area suggests that the advance sand is not as widespread as previously believed. In addition, the results of drilling on-site by AESI indicate that the advance sands are not as deep on all portions of the Lone Star site as previously suspected. Mapping shows that the base of the advance sand rises towards the north and south (Booth, 1991).

In viewing the geologic sections for both the site and for the regional conditions, it should be remembered that the recent geologic history of the Puget Sound Basin resembles the existing conditions. The repeated glaciations in the Puget Sound area carve the sediments about every 50,000 years. Hence, an orderly sequence of laterally continuous geologic strata are not typically present. Instead, sediments are draped over pre-existing hills and deposited into pre-existing valleys. Geologic deposits may not be laterally continuous for large distances. This explains the apparent distribution of advance sands in sections on Figures 10 and 11. The sands appear to have been deposited in a lower area or valley between adjacent hills or uplands.

3.3 Soils

In general, the site is mantled by a series of soils related to the underlying geologic units. Where the advance outwash is close to existing grades, Everett soils are present. Where the till soils are present close to existing grades, Alderwood soils have developed. The distribution of these soils mimics the geologic map of the site. The existing soils on the site are presented on Figure 8. This map was created using the SCS process and the actual geologic units found on-site. (SCS 1973)

Existing Soils Mapping by the SCS shows AKf soils along the bluff. These soils form in areas with Alderwood and Kitsap soils. No Kitsap soils have been identified on the site. Hence, our map for this project reflects the actual soils that have been encountered on the site.

3.4 Groundwater

3.4.1 General

Groundwater is any water present beneath the surface. It occurs in open spaces in soil, sand, gravel, and other sediments, and is a major element of the hydrologic cycle. The hydrologic cycle begins with rain, which infiltrates relatively quickly into the ground on the site. Once water enters the ground, it will flow downward under the force of gravity through porous and permeable materials, such as gravel and sand, until reaching a barrier, such as a layer of compact till or clays and silts. These barriers are referred to as aquitards and consist of soils with a lower permeability than the soils above them. These barriers have varying effectiveness slowing the downward movement of the water, depending on their actual permeability relative to the surrounding soils.

Once water encounters a barrier, it accumulates above the barrier and will flow towards areas of lower head (lower groundwater levels). Where this underground lateral movement of water is near the ground surface, it is commonly referred to as the interflow network. At some point, the water reaches a point where the barrier meets the surface where the water flows out as a spring or seep. Otherwise, the water continues its downward movement at a slower rate based on the permeability of the aquitard to recharge deeper groundwater bodies. When a significant amount of water remains in-place over time, it forms an aquifer.

There are two current systems for classifying groundwater bodies on Maury Island. The first is the methodology developed by Carr and Associates. This system divides the aquifers into two basic units, the Principal Aquifer and the Deep Aquifer. A subsequent study, the Groundwater Management Plan, identifies the groundwater bodies as Hydrostratigraphic Zones with the zones defined by the elevation of the groundwater table. For this report, both classification systems will be followed. The Hydrostratigraphic system recognizes the complexity of the geology and classifies the groundwater bearing zones by the elevation of the static water level. The following table summarizes the hydrostratigraphic system.

Hydrostratigraphic Zone	Hydraulic Head (static water elevation relative to sea level)	Range of elevations	Probable Aquifer Correlation from Carr
Zone 1	Average elevation 255	175-300	Principal Aquifer
Zone 2	Average elevation 97	50 to 175	Principal Aquifer
Zone 3	Average elevation 18	Classification depends on depth of well	Deep Aquifer
Zone 4	Average elevation 11		

It should be noted that the Hydrostratigraphic zones do not directly correlate with geologic strata. However, it is likely that adjacent wells in the same hydrostratigraphic zone have significant hydraulic continuity, regardless of the actual stratum that is screened for the individual wells. In addition, numerous wells are present that would fall into the Hydrostratigraphic Zone 2 but that are not screened in advance sands. These wells are producing water from permeable soils within pre-Vashon geologic deposits.

The AESI report refers to the groundwater bodies as being the primary Aquifer (the Principal Aquifer) and the Sub-Sea Level Aquifer (the deep Aquifer).

Based on the current information, three main groundwater regimes have been identified in the vicinity of the site. These regimes include (1) Interflow network; (2) Principal aquifer, and (3) Deep aquifer.

3.4.2 Interflow Groundwater

Interflow is defined as runoff due to that part of the precipitation that infiltrates the surface soil and moves laterally through the upper soil horizons toward the stream channels. The interflow is included in direct runoff and is part of the Flood Hydrograph.

Terra Associates was present during the excavation of Exploration Pits EP-16 through EP-28. These exploration pits were excavated by AESI during January of 1999. The purpose of the pits was to further define the extent of the Vashon till and to observe the relative condition of interflow groundwater that may be present.

Based on our observations and subsequent data documented in the AESI draft addendum, it is apparent that a well developed and defined interflow water body is not present on the Lone Star site. However, local pockets of interflow were observed above the till in some locations. Due to both the thin discontinuous nature of the till and its apparent higher permeability, no significant interflow network has developed that migrates to off-site locations. This is illustrated by the following observed conditions. Exploration Pit EP-17 encountered heavy seepage at a depth of about 12 feet below existing grades. Exploration Pit EP-18 was then excavated north and downgradient of Exploration Pit EP-17. In Exploration Pit EP-18, no till aquitard was encountered and no seepage was present.

Shallow monitoring wells (P-1 and P-2) were installed in the northwestern portion of the site. This portion of the site appears to be underlain by a layer of till that is several feet thick. Light seepage was encountered at 4.5 feet during the excavation of Exploration Pit EP-19. No significant water was encountered in shallow monitoring wells constructed in P-1 and P-2.

The weather preceding the excavation of the supplemental test pits was wetter than normal and an interflow regime would have been expected to have been present if geologic conditions allowed its development. This illustrates the likely presence of windows of higher permeability soils within the till that allow the near-surface interflow to infiltrate deeper into the ground to recharge the principal aquifer.

3.4.3 Deeper Perched Water

AESI had a series of geophysical measurements made in the casing for Observations Wells OBW-5, OBW-6, and OBW-7. These measurements included a neutron log. The neutron logging technique is discussed in detail in the 1999 AESI addendum report. In general, the neutron logging technique measures concentrations of hydrogen. Each molecule of water has two atoms of hydrogen. Hence, areas with higher moisture contents have higher readings on the neutron log. The results of the neutron logging indicate that perched groundwater bodies were present in Observation Wells OBW-6 and OBW-7. The depths of these water bodies was 45 feet and 200 feet, respectively. Each of these perched water bodies is expected to be a local pocket of coarser grained soils underlain by discontinuous silts or silty sand layers. None of the deeper perched water zones are believed to be laterally continuous.

Based on field studies conducted and our observations, the following conclusions regarding the perched (interflow) water zones can be drawn.

- Discontinuous interflow networks are present on the site.
- The till that forms the aquitard allowing interflow to form is discontinuous and relatively thin.
- No significant off-site movement of groundwater occurs in the shallow interflow network.
- Precipitation that infiltrates the site soils remains beneath the site and contributes to the principal aquifer.

3.4.4 Principal Aquifer

Groundwater was encountered in all of the exploration borings performed. Figure 3 illustrates the locations of the exploration borings. A summary of the on-site water levels is shown in Table 1. The static water level is shown on Figure 5. Appendix C contains a memo by AESI that presents a summary of the static water levels information collected to this time. The data collected indicate water fluctuations on the order of one foot. Additional data is currently being collected. Three of the monitoring wells have been provided with data loggers to collect continuous data. The variations seen in the daily data could be a result of changing barometric pressures. Observation Well OBW-9 may have a tidal influence as well.

The water encountered in the exploration borings is identified as the Principal aquifer. This groundwater regime is an unconfined aquifer that is present within the Vashon advance outwash sediments and corresponds to the "Principal Aquifer" of Carr (1983). The principal aquifer is within Hydrostratigraphic Zones 1 and 2.

Groundwater flowing beneath the site has been determined to discharge directly into Puget Sound. The site appears to be a discharge zone for water from the principal aquifer on this part of Maury Island. Some of the water beneath the site likely contributes to deeper aquifers in the immediate vicinity of the site.

Table 1
Static Water Elevation Summary
Lone Star Pit/Maury Island
King County, Washington

Well Number	Ground Surface (reference elevation)	2-4-98	2-19-98	3-3-98	12-17-98	2-19-99	2-25-99	3-30-99	4-28-99
OBW-1	297.96	51.65	51.49	51.72	52.02	51.73	51.89	52.21	52.54
OBW-2	355.34	48.36	48.25	48.57	48.74	48.41	48.64	48.65	48.66
OBW-5	268.42					85.01	85.5	85.78	85.96
OBW-6	275.62					56.76	57.02	57.38	57.68
OBW-7	306.74					41.41	41.96	41.74	41.42
OBW-8	87.1					20.4	20.73	20.34	19.84
OBW-9	44.91					19.1	19.3	18.68	18.40

Note: All reference and static water elevations are provided by AESI.

3.4.5 Deep Aquifer

Although not encountered in the subsurface explorations completed on the site, prior investigators have identified a Deep Aquifer below the Principal Aquifer. Insufficient information is currently available to determine the extent and flow direction of this aquifer. However, given the lack of off-Island recharge sources, the flow of water in this deeper unit would tend to be radially away from the center of the islands towards Puget Sound. The deep aquifer corresponds to Hydrostratigraphic Zones 3 and 4.

Recharge to the deep aquifer from the overlying Principal Aquifer occurs through the aquitard either in a relatively slow manner or through areas where glacial erosion has removed the aquitard creating windows connecting the aquifers. The amount of recharge is limited by the permeability of the aquitard and other intervening strata.

The aquitard that divides the Principal Aquifer from the Deep Aquifer has not been specifically identified or encountered in the borings performed on-site. AESI has identified that several of their borings have penetrated the

full height of the advance outwash and have encountered an older pre-Vashon soil that they refer to as the undifferentiated pre-Vashon unit. While the pre-Vashon soils are finer-grained and exhibit a lower permeability, they are not the types of soils that are typically associated with aquitards. Hence, it is possible that the Principal and Deep Aquifer are in hydrologic continuity at the location of the site. This would help explain the similar static water levels in the Iliad Well and the Sandy Shores Well, both completed in a deeper soil unit than either the advance outwash (the Principal Aquifer) and the on-site wells completed by AESI.

3.4.6 Existing Wells and Water Rights

Adjacent well logs available from the Washington State Department of Ecology are in Appendix B of this report. Figure 9 shows the approximate location of the water wells adjacent to the Lone Star Site. These wells are located by quarter-quarter sections. Thus, only one point was made in each quarter-quarter section regardless of how many wells were located within the individual quarter-quarter section. Further definition of the actual location of the well is difficult without field inspection of individual properties. Existing water rights are summarized in the 1998 AESI report. The validity of the listed water rights is not known. Several of the local water systems may be over drawing water beyond their permitted quantity (Vashon-Maury Island Groundwater Committee, 1998). In addition, no water right certificate exists for the Gold Beach water system. It is also not known which of the water right certificates, applications, or claims are no longer valid due to lapse in beneficial use of the water permitted by the certificate.

Generalized geologic cross sections were drawn based on our review and interpretation of the water well logs. It must be noted that the water well logs are generally filled out by the well driller. It is our experience that the drilling industry uses a wide variety of terms to describe these soils typically found in the Puget Sound basin. The terms used by the drilling industry have not corresponded well with terms used by geologist and engineers. Thus, a certain level of interpretation is needed in determining the stratigraphic conditions present at individual wells.

Dockton Water Company

The Dockton Water Company gets their water from three sources, Dockton Park Springs, Hake Springs, and the Sandy Shores Well. The Sandy Shores Well is discussed later in this section of the report. The aquifer that is tapped by the Hake Springs appears to be the Primary Aquifer in Hydrostratigraphic Zone 1. The elevation of the Hake Springs area is on the order of Elev. 100. The elevation of the Dockton Park Springs field is on the order of Elev. 30 to 50. Based on the geologic sections presented on Figures 10 and 11, it appears that the Dockton Park Springs are located in a permeable soil unit within the pre-Vashon sediments. Both springs are marked on Figure 9. The Dockton Water Company has a certificate of water rights for these two springs.

The elevation of the Dockton Park Springs field is roughly equivalent to the elevation of the Principal Aquifer at the Lone Star site. Given these equivalent elevations, flow from one area to the other would not occur. This indicates the presence of hydraulic divide somewhere towards the center of Maury Island.

If the water from the Dockton Park Springs is within water bearing zones within a regional aquitard, the recharge area would have to be higher than the static water levels observed beneath the Lone Star Property. Hence, in either scenario, the Lone Star site is not a recharge body for the Dockton Park Springs.

The Hake Springs are at an elevation above the static water level in the monitoring wells on the Lone Star site. Therefore, if there is continuity between the Hake Springs and the Lone Star site, the Lone Star site becomes a point of discharge as opposed to recharge for Hake Springs.

Iliad Well

The water found in the Iliad Well (22 3E-21 P-1) appears to have its origins in the Deep Aquifer. This interpretation is based on the location of the intake screens from 511 to 520 feet below the ground surface. The Iliad Well penetrates what appears to be a thin till cap then advance outwash to a depth of about 180 feet below existing grades. Beneath this depth, the well is in a series of clays, silts, and gravels. These deeper deposits appear to be pre-Vashon in age and may include a till soil of pre-Vashon age. The ground surface is approximately Elev. 300 at the well head location. This would place the Iliad Well in Hydrostratigraphic Unit 3 or 4.

The Iliad Well has a water right certificate.

Sandy Shores Well

The Sandy Shores well (22 3E 32 C-1) is operated by the Dockton Water Company and is located near the intersection of SW 270th and 94th Avenue SW. This well was constructed in 1961. Details of the construction and testing are presented in a brief report by Robinson and Roberts, 1961. This well appears to have encountered water in the Principal Aquifer during drilling. This water level is recorded on the drilling log as a saturated zone with a bottom depth of 275 feet and a top of 265, approximately.

The drilling continued down past this upper saturated zone through a sequence of silts and silty sands to a deeper sand body. The static water level for the deeper sand unit is shown as being at a depth of 238.7 feet below the ground surface. This corresponds with approximately level 61 feet. This places the Sandy Shores Well in the Hydrostratigraphic Zone 2. This static water level is higher than anticipated given the elevation of the screen for the well. This suggests significant hydraulic continuity with the Principal Aquifer. The static water elevation is similar to the elevation of the static water level on the Lone Star site. Hence, the Sandy Shores Well appears to be crossgradient of the Lone Star site.

The Sandy Shores Well has a water right certificate.

Gold Beach Wells

The adjacent wells used by the Gold Beach Water Company draw their water from the Principal Aquifer. These two wells are identified as Wells 22 3E 28 B-1 and B-2. The geologic units that produce the water at Gold Beach

are not advance sands commonly associated with the Principal Aquifer (Rongey, 1998). However, the primary distinction here is the hydrologic continuity of the groundwater.

The static water levels in the Gold Beach Wells are consistent with the Principal Aquifer and Hydrostratigraphic Unit 2. The static water level in one of the wells in the winter of 1998 was at approximately Elev. 29 (AESI 1998). This is similar to the elevation of the groundwater on the Lone Star site in the same proximity to the face of the primary bluff. Hence, the Gold Beach Wells are crossgradient from the Lone Star site. The actual groundwater conditions may put the Gold Beach Wells on the northern limb of a groundwater mound that is present immediately north of the Lone Star site, which would further reduce hydraulic continuity between the Lone Star site and the Gold Beach Wells.

There is an application for water rights for the Gold Beach Wells.

3.4.7 Existing Hydrologic Budget

For evaluation of the site's groundwater budget/balance, an average annual precipitation of 40 inches was used. Annual rainfall can vary by up to 50 percent. The value of 40 inches is not intended to be an exact amount, only a representative value.

The rain that falls on this site has five possible fates:

1. Interception and Direct Evaporation - Forested sites typically have higher amounts of interception due to the height and amount of canopy together with the brush understory. Thus, there are two layers of interception possible in a forested area. The water loss through interception is considered to be evaporation. During mining operations, the removal of vegetation will eliminate the interception component from the balance. However, direct evaporation from the surface and near-surface soils will occur.
2. Transpiration - Transpiration is the water taken up through plant roots and used in the life process transporting nutrients up from the soil to the branches and leaves of the vegetation and trees. The transpiration occurs through the leaves of the plant. During the winter, when most of the rain falls, the vegetation is largely dormant. Thus, the majority of the transpiration occurs in the summer. The amount of transpiration is dependent upon the climate, the amount of solar energy, and the nature of the vegetation on the site.
3. Surface Runoff - Even though surface runoff is experienced on a day to day basis in developed areas of the Puget Sound, it is actually a relatively rare event in undisturbed forested areas and does not appear to be an important element of the hydrologic cycle on the Lone Star site. Runoff has only been noted immediately along the off-site paved roads and the on-site unpaved roads. The runoff that is commonly associated with forested sites is through the interflow to creeks and streams.
4. Groundwater Recharge - The groundwater recharge is the amount of water that actually travels beyond the surface soils and beneath the root zones to become part of the aquifer that underlies the ground surface. This recharge is then available for either deeper infiltration to deeper aquifers or lateral transport through the upper aquifer.

5. Pumped for use or discharge to Puget Sound.

The water budgets for till water sheds have been the focus of a recent study by the U.S. Geologic Survey (USGS). The results of their studies are presented in a report entitled *Recharge From Precipitation in Three Small Glacial Till Mantled Catchments in the Puget Sound Lowland, Washington*. (Bauer 1997). This study was conducted in Puget Sound to help estimate the amount of recharge that occurs through till sites. The groundwater cycle and recharge issues are important issues throughout the Puget Sound area. Although the Lone Star site has not been found to have a continuous till blanket, the results of the analysis of the hydrologic budgets at the water sheds studied by the USGS is beneficial in estimating the existing and possible future groundwater budgets on this site. The USGS found the following values for the differing outputs of the hydrologic budget. These budgets ignore the ultimate discharge of groundwater into Puget Sound.

Table 2
Typical Till Site
Groundwater Budget Summary

Hydrologic Cycle Component	Land Type	High Value (%)	Low Value (%)	Average (%)
Interception	Forest	47	36	41
	Pasture	13	13	14
Transpiration	Forest	33	27	30
	Pasture	39	24	32
Runoff	Forest	22	11	18
	Pasture	62	43	53
Recharge	Forest	17	3	8
	Pasture	7	5	6

Notes: This summary is based on percentages of precipitation. The rainfall in the three water sheds studied ranged from about 33 inches to 45 inches during the period of the study.

On the Lone Star site, since there is no observed runoff and no significant interflow, the runoff element of the budget is close to zero. The runoff element in the summary above is based on measurements in surface water flows such as creeks or streams that leave individual water sheds. The runoff values are not a measurement of gross overland flows. The runoff values represent interflow that feeds creeks. The lack of runoff on the Lone Star site is further illustrated by a lack of creeks in the vicinity of the site. In addition, the till that is present beneath the site is discontinuous and no coherent interflow water body has been identified. Hence, a reduction of the portion of the

budget that would have been for surface runoff can be used for conceptual modeling of the site. For the Lone Star site, it is anticipated that the following groundwater budget would apply. This is based on using the average values presented above and an annual rainfall of 40 inches per year. Table 3 assumes the site to be a till site following the pattern of the water sheds studied by the USGS. The far right column presents our interpretation of the likely equivalence of the published values for a till site versus the Lone Star site conditions. Note that due to rounding, the sums of the individual components do not add up to 40 inches.

Table 3A
Forested Area
Lone Star Site Comparison

Hydrologic Cycle Component	Hydrologic Budget (in inches, based on 40 inches of rain)	Comments
Interception	16.4 inches	Equivalent
Transpiration	12.0 inches	Equivalent
Runoff (Recharge)	7.2 inches	Overstated for Lone Star site-
Recharge	3.2 inches	Understated for Lone Star site

Table 3B
Active Mining Cell
Lone Star Site Comparison

Hydrologic Cycle Component	Hydrologic Budget (in inches, based on 40 inches of rain)	Comments
Interception	5.6 inches	Equivalent
Transpiration	12.8 inches	Overstated for Lone Star site
Runoff (Recharge)	21.2 inches	Overstated for Lone Star site
Recharge	2.4 inches	Understated for Lone Star site

The runoff values presented above are for discussion purposes. In the inactive areas of the existing mine, the values for interception are likely lower due to the sparse nature of vegetation. Given the lack of runoff in both the existing forested area and the inactive mine area, the actual hydrologic budget is expected to be as summarized in the following table.

Table 4
Hydrologic Budget Summary
Lone Star Pit/Maury Island
King County, Washington

Hydrologic Cycle Component	Land Type	Hydrologic Budget (in inches, based on 40 inches of rain)	
Interception	Forest	16.4 inches	
Interception	Active mine area (Pasture)	5.6 inches	
Transpiration	Forest	12.0 inches	
Transpiration (Add to Recharge)	Active mine area (Pasture)	12.8 inches	
Runoff portion of till budget (Add to Recharge)	Forest	7.2 inches	
Runoff portion of till budget (Add to Recharge)	Active mine area (Pasture)	21.2 inches	
Recharge	Forest	3.2 inches	
Recharge	Active mine area (Pasture)	2.4 inches	
Total Recharge	Forest	7.2 + 3.2=	10.4 inches
Total Recharge	Active mine area	12.8 + 21.2 + 2.4=	36.4 inches

Note: Due to rounding of values, the sum does not equal 40 inches.

From the summary above, it is evident that additional recharge is occurring on the previously mined portions of the Lone Star site as a result of clearing of the forested areas to allow site mining activities.

The speed at which the recharge occurs is dictated by several factors. Recharge does not begin immediately upon the start of the rainy season in late October or early November. The near-surface soils are dry at that time from the summer drought and the transpiration of water by the vegetation. The soil moisture content in the near-surface soils is expected to be at or below the wilting point. The wilting point is the level of moisture in the soil that is beyond the capacity of the roots to extract. These dried soils will absorb water until their field capacity has been reached. The field capacity is the amount of water that will be held by capillary action against the downward pull of gravity. Water contents above the field capacity will be available as recharge if not transpired by the vegetation.

The lag between the rainy season and observable effects on the static water level are delayed by about three months per 50 feet of well depth (Carr 1983). For this site, the existing cover soils are 300 feet. This would put the lag in groundwater response at up to one year. The thickness of the over burden would also smooth out and attenuate the differences in water levels versus the peaks in seasonal rainfall. The actual cycle should be visible on the groundwater monitoring data that is currently being generated.

3.4.8 Groundwater Quality

The existing groundwater quality for Monitoring Wells OBW-6, OBW-7, and OBW-9 are shown on Table 5. The values that exceed the drinking water standard are shown in bold and are discussed following Table 5.

Table 5
Water Quality Results
Principal Aquifer
February 22, 1999
Sampled by AESI
Lone Star Pit/Maury Island
King County, Washington

Water Quality Test	OBW-6	OBW-7	OBW-9	Drinking Water Standards Chapter 246-290 WAC
pH	6.9	7.1	7.6	6.5 – 8.5
Total Alkalinity (mg/l as CaCO ₃)	48	82	94	NE
Total Organic Carbon	< 1	< 1	< 1	NE
Chloride	3.4	10	3.3	250
Conductivity (µmhos/cm)	130	250	190	700
Color (color units)	20	20	10	15
Total Cyanide	< 0.005	< 0.005	< 0.005	0.2
Fluoride	0.09	0.07	0.13	4
Hardness	49	100	80	NE
Nitrite Nitrogen	0.004	0.026	0.001	NE
Nitrate	0.95	5.0	< 0.25	10
Nitrite	< 0.25	< 0.25	< 0.25	1.0
Total Oil and Grease	< 1	< 1	< 1	NE
Total Petroleum Hydrocarbon	< 1	< 1	< 1	NE

(Continued on next page)

Table 5 (Continued)
Water Quality Results
Principal Aquifer
February 22, 1999
Sampled by AESI

Lone Star Pit/Maury Island
King County, Washington

Water Quality Test	OBW-6	OBW-7	OBW-9	Drinking Water Standards Chapter 246-290 WAC
Total Suspended Solids	1.0	2.0	1.0	NE
Sulfate	13	21	10	250
Surfactants	0.08	0.15	0.13	NE
Turbidity (NTU)	6.1	6.7	0.78	1
Aluminum	0.06	0.02	< 0.001	NE
Antimony	< 0.001	< 0.001	< 0.001	0.006
Arsenic	0.002	0.002	0.004	0.05
Barium	0.005	0.010	0.008	2.0
Beryllium	< 0.0002	< 0.0002	< 0.0002	0.004
Calcium	6.7	15	15	NE
Cadmium	0.003	< 0.002	< 0.002	0.005
Chromium	< 0.006	< 0.006	< 0.006	0.1
Copper	0.016	0.017	0.006	NE
Iron	0.77	0.88	0.13	0.3
Mercury	< 0.0008	< 0.0008	< 0.0008	0.002
Magnesium	7.8	16	10	NE
Manganese	0.03	0.070	0.23	0.05
Sodium	6.2	8.7	6.8	NE

(Continued on next page)

Table 5 (Continued)
Water Quality Results
Principal Aquifer
February 22, 1999
Sampled by AESI

Lone Star Pit/Maury Island
King County, Washington

Water Quality Test	OBW-6	OBW-7	OBW-9	Drinking Water Standards Chapter 246-290 WAC
Nickel	< 0.01	< 0.01	< 0.01	0.1
Lead	< 0.001	0.001	< 0.001	NE
Selenium	< 0.001	< 0.001	< 0.001	0.05
Silver	< 0.01	< 0.01	< 0.01	0.05
Thallium	< 0.001	< 0.001	< 0.001	0.002
Zinc	0.038	0.060	< 0.002	5.0

Notes: Units in milligrams per liter/parts per million (mg/l) unless otherwise noted.

NE indicates that no maximum contaminant level (MCL) has been established for this parameter.

The water from the monitoring wells meets all existing drinking water standards for primary and secondary characteristics with the exception of iron, manganese, turbidity, and color. Iron and Manganese are secondary water quality standards and are based on aesthetics. Elevated iron and manganese cause stains on plumbing fixtures. Neither of these two MCLs are health driven.

It is likely that the two parameters of color and turbidity are elevated due to the nature of the well development and sampling. Both of these parameters are typically elevated in new water wells. We expect that further development and pumping from the wells will finish the development process and these parameters will decrease through time.

4.0 PROJECT IMPACTS AND MITIGATION

4.1 Citizen Concerns

The primary issues analyzed are:

- Would mining as proposed affect recharge of the aquifer system? Specifically, would groundwater levels be altered in the vicinity of the infiltration pond, and if so, how would this alteration affect those areas currently receiving broad areal recharge?
- Would the mining activity breach an aquifer or otherwise impact adjacent groundwater wells being used by local residents?
- Would the mining activity have any effect on the quality of the groundwater?

As discussed in the following sections, the proposed mining will affect the recharge patterns on the site. During mining, the effect will be to increase the amount of water that recharges the aquifer. While this will result in local mounding of the groundwater, no reduction in the amount of water available to recharge the aquifer is expected. Mounding will occur under the final infiltration ponds for the ultimate finished condition of the site. However, by dispersing the infiltration facilitates throughout the site, the effects will be reduced.

No aquifers will be breached or exposed in the course of the mining operation. No measurable impact to adjacent groundwater wells is expected as a result of the proposed action. No wells specifically extract water from the Principal Aquifer adjacent to the site.

4.2 Groundwater Recharge

Impact

There are concerns that the proposed mine will impact aquifer recharge and decrease the amount of drinking water present on Maury Island. The impact of the no action alternative would be the same as the existing conditions. No measurable change in the groundwater levels or recharge quantities would be expected from the no action alternative.

For the proposed action and the two alternatives, the removal of 300 feet of soils will impact the recharge of the groundwater. First, the recharge will occur much more rapidly than at the current time. Current information indicates that the groundwater cycle on this site may be up to one year in length. Removal of the sand to leave 15 feet of material between the static water level and the ground surface will reduce the lag time to less than 20 days.

Placement of till soils in the floor of the pit and compaction of the till soils during placement could reduce the permeability of the floor of the pit, which would increase runoff. Increased runoff to the surface water treatment and infiltration ponds could result in surface flows to Puget Sound. This would be a loss of water that otherwise would have recharged the aquifer. Loss of the water through surface flows to Puget Sound from the Lone Star site could result in a steeper groundwater gradient, which would draw water faster from off-site upgradient locations, reducing the amount of water that would be present as storage or potential recharge to the Deep Aquifer.

Mitigation

As stated earlier, the existing condition of the previously mined areas of the Lone Star site allows more recharge to the underlying aquifer than the undisturbed condition. This is due to the lower interception that occurs under the sparse vegetation that has replaced the forest. In addition, as the mine is developed, additional infiltration and recharge will occur as each cell is cleared of vegetation. This will create local mounding of the groundwater with some locally higher groundwater gradients beneath the active mine cells. This, in turn, will increase the amount of water present in the aquifer as shown in the following table. Due to rounding, the values do not add up to 40 inches.

Table 6
Hydrologic Budget
Forest/Active Mine Cell
Lone Star Pit/Maury Island
King County, Washington

Hydrologic Cycle	Forest	Exposed Soil/Active Mine
Interception (Evaporation)	16.4 inches	5.6 inches (using value for pasture)
Transpiration	12.0 inches	0 inches
Runoff	0 inches	0 inches
Recharge	10.4 inches	36.4 inches

Note: Due to rounding, values do not add up to 40 inches.

Hence, a significant increase in the amount of water available for recharge will be present during the mining operations.

Following completion of the mining operations, the existing infiltration pattern should be mimicked to the greatest extent possible. This can be done first with the use of benches on the final slopes of the pit. These benches should be provided with a reverse slope back into the hillside and as low a lateral gradient as possible to encourage infiltration on the higher slopes of the pit. The soils exposed in the pit walls should remain stable with this course of action. Local erosion issues may occur during pit operation that can be resolved prior to and during final reclamation. The benches should be provided with a lateral slope towards a central location where any accumulated runoff could be concentrated in an infiltration facility at the toe of the final slope. Rip-rap lined channels could be used to convey the accumulated runoff down the face of the slope to the toe for ultimate infiltration.

Intermediate water treatment and infiltration facilities should be created to collect runoff from the roads that will enter the pit from off-site. These facilities should be located along the toe of the created final slopes at the base of each of the entry roads. This will spread the infiltration of water out across the site and reduce the amount of mounding and disruption of the existing groundwater gradient that exists.

Excessive compaction of soils placed over the floor of the pit during reclamation should be avoided. Soils compacted incidental or subsequent to placement should be ripped and scarified to increase their permeability and reduce the amount of runoff that will be created.

Finally, as the mine is nearing completion, recharge and infiltration facilities will need to be dispersed across the entire site rather than concentrated near the dock as currently proposed. The infiltration facilities will need to be designed to infiltrate all of the precipitation that currently falls on the site without spilling water to Puget Sound. There is no evidence of surface flows of water from the site to Puget Sound at this time. This will require specific analysis of individual recharge/infiltration facilities to assure that excessive mounding does not occur beneath the site resulting in surface runoff and overland flow of water beyond the control facility. An additional thickness of sand beneath the floor of the mine greater than the 15 feet proposed may be required to provide storage for the additional volume of water and its infiltration to allow for mounding without creating runoff.

4.3 Groundwater Quality

Impact

As discussed earlier in this report, the site is underlain by a thick sequence of moderate to high permeability sands. The static water level of the Principal Aquifer is at approximately Elev. 80 feet and lower beneath the site. The Principal Aquifer beneath the site is a component of the drinking water resource on Maury Island serving as part of the drinking water resource and as a recharge body for deeper aquifers. Mining of the site will remove the sands and gravels to within 15 feet of the groundwater table. Based on our review of the groundwater elevations data developed to date and the regional geologic information available for this portion of Maury Island, the groundwater flow beneath the site is towards Puget Sound. Some component of the groundwater will flow downwards to recharge deeper aquifers. Even the component of flow in the sub sea level aquifer would be expected to be towards Puget Sound.

Concerns have been voiced that the removal of the sand and gravel due to mining could decrease water quality beneath the site. The groundwater quality impacts are suspected due to the removal of the “filtering media”, the sand, and the operation of heavy construction equipment on the site. The current project plan will leave at least 15 feet of native soil between the floor of the pit and the static water level. Under the current project plan, the Principal Aquifer will not be exposed in open excavations.

In uncontrolled mining operations, water quality could be impacted from improper excavations, a lack of surface runoff control facilities, and releases of engine fluids from heavy equipment. The proposed borrow pit is covered under the Clean Water Act. The proposed borrow pit is required to have a National Pollution Discharge Elimination System (NPDES) permit.

While no drinking water wells are suspected of being downgradient of the Lone Star site, Washington State has an antidegradation policy that is intended to preserve the quality of groundwater in Washington State regardless of current beneficial uses.

The potential sources of groundwater quality degradation are the mining operations and the use of heavy equipment on the site. The heavy equipment will require fuels and lubricants. Occasional mechanical repairs are typically performed in the field on such equipment. The actual mining operation itself is not expected to create contaminated runoff. No additional chemicals are proposed to be imported to the site during pit operation beyond the fuels and lubricants that will be used by equipment on-site. Petroleum spills are readily detected and can be promptly cleaned up. This is the main type of contamination expected during mining operations. Spills of petroleum hydrocarbons are required to be reported and remediated under existing state laws and regulations.

State Law specifies that reporting and cleanup of spills of hazardous materials be performed. Thus, no specific mitigation is needed for potential spills since this is already required under state law.

For potential issues due to turbidity of the storm runoff on the site, appropriate sedimentation facilities will be used, such as hay bails, silt fences, and infiltration ponds. The Best Management Practices (BMPs) for these issues are presented in the *King County Stormwater Control Manual*.

Finally, it should be noted that the sands that are present at the base of the proposed mining operation are generally consistent with the specification for water treatment sand for stormwater management facilities. These specifications are listed in Table 6.5.2.C of the *1998 King County Storm Water Design Manual*. The site sands generally meet the specifications with the exception of the amount of fines present in the native site soils. This will act to decrease their relative permeability and further enhance their ability to filter storm runoff that would infiltrate the native site soils. The sand specification listed above is for sand filters for storm runoff treatment. The thickness of the sand filters in these facilities is two feet. Hence, the remaining 15 feet of sand above the static water level will be sufficient to filter most pollutants that are adsorbed onto sediments in the stormwater runoff. No dissolved pollutants are expected to be present in stormwater runoff from the site.

The potential impacts due to arsenic, cadmium, and lead in the site topsoils are addressed separately by Lone Star as part of their site cleanup plan.

Thus, under the proposed action, the two options, and the no action alternative, no impacts to the groundwater quality are expected to occur.

Environmental Protection

To assure that the excavation does not encounter groundwater and that the minimum thickness of soil cover remains over the aquifer, additional borings can be performed during pit operations to determine spot elevations of the groundwater surface. The additional borings should be provided with sufficient survey control to accurately measure the static water level. Appropriate correction factors can be added to replicate the seasonal high water table based on prior groundwater monitoring in the existing monitoring wells to verify that the thickness of the remaining sand is based on the maximum static water levels.

The operations on the property can be performed in accordance with the BMPs presented in the Puget Sound Manual for all aspects of the site development

The county should require that the operators follow these BMPs:

- SWMM BMP S1.10 Fuelling Stations
- SWMM BMP S1.20 Vehicle/Equipment Washing and Steam Cleaning
- SWMM BMP S1.30 Loading and Unloading Liquid Materials
- SWMM BMP S1.40 Liquid Storage in Above Ground Tanks
- SWMM BMP S1.50 Container Storage of Liquids, Food Wastes or Dangerous Wastes
- SWMM BMP S1.60 Outdoor Storage of Raw Materials, By-Products or Finished Products.

Quarterly monitoring should be required prior to operation of the pit to establish existing baseline water quality standards. During pit operations, annual groundwater samples should be taken to determine the actual condition of the groundwater. Action levels based on Washington State laws and regulations should be followed. The applicable laws and regulations will be spelled out in the NPDES permit for the site. The test results should be promptly submitted to the appropriate regulatory agencies for review. If groundwater impacts are noted, appropriate additional mitigations can be performed. For instance, if petroleum hydrocarbons are detected in monitoring wells, the source of the spillage can be located and appropriate remedial actions taken.

4.4 Dust Control Water

Impact

The operation of the borrow pit will require the use of water to control dust during operation. Lone Star Northwest has stated that a maximum amount of water that may be needed is on the order of 10,000 gallons of water per day. The water will need to be brought in from an off-site source. There has been concern that this consumptive use of water could tax the existing water resources on the island. All of the water used for dust control is assumed to evaporate. No recharge to the aquifer would occur as a result of typical application of water for dust control. The daily use of water on Vashon and Maury Island is currently at about 1,200,000 gallons per day (Vashon-Maury Island Groundwater Committee, 1998). This represents a potential increase in water use of 0.8 percent on days when the maximum amount of dust control would be needed. However, the operation will not be in use continuously and on rainy or overcast days there will be no or a reduced need for water from off-site sources for dust control so the actual overall impact will be much less than 0.8 percent of the existing daily demand.

The use of a focused application of water will further reduce the amount of water that would be needed to control dust. The use of “mistifiers” to keep a constant moisture content of the soils in the conveyor belt system would further reduce the potential need of water for dust control.

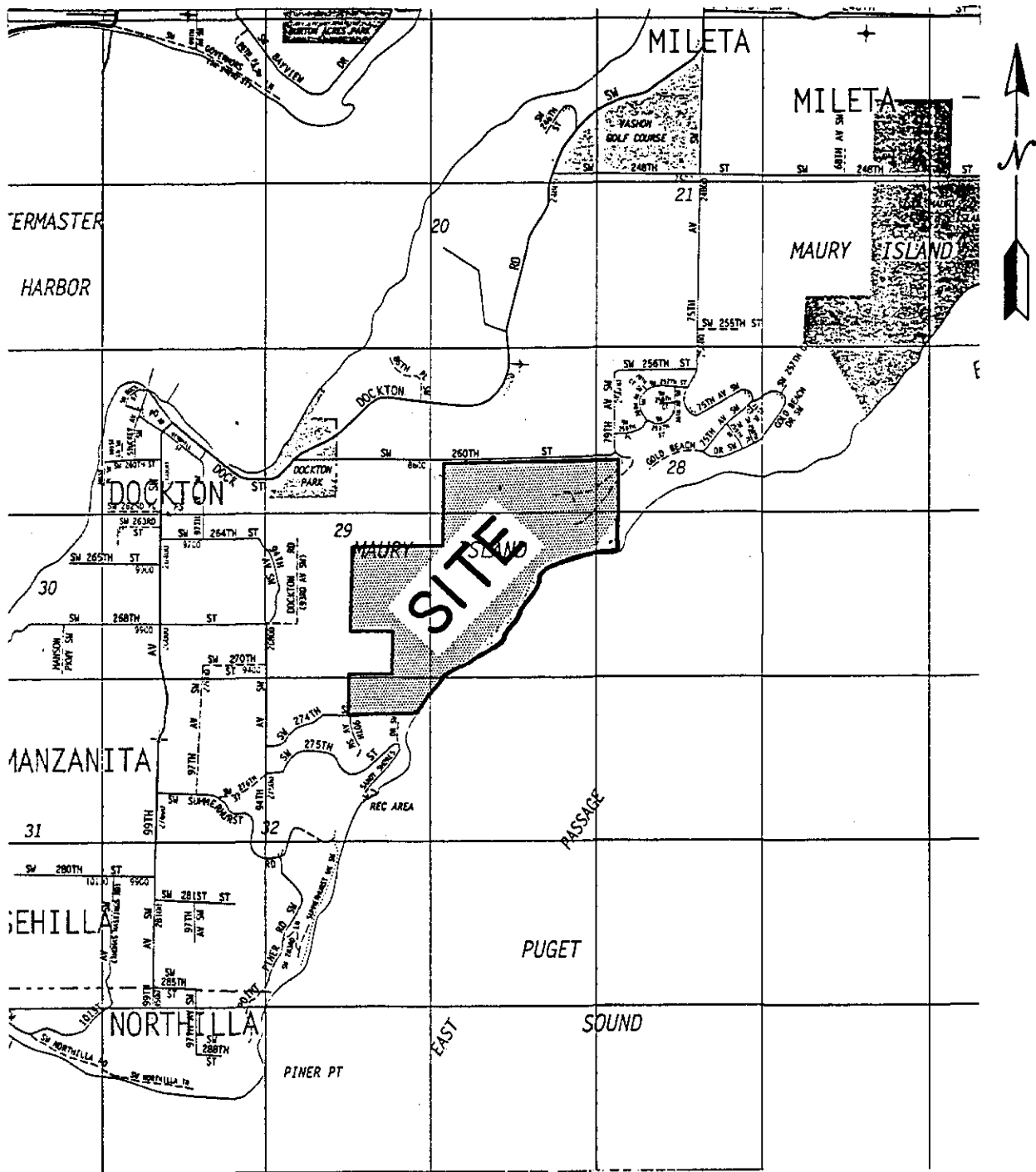
The impact under the two alternatives would be similar but somewhat less due to the reduced production. The impact under the no action alternative would be the least since little if any dust control measures would be expected under the existing operations.

Mitigation/Environmental Protection Measures

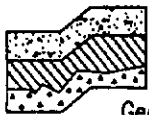
To reduce the potential impact of the consumptive use of water for dust control, the county could require that the proponent purchase water from a variety of water purveyors. This would spread the potential impact across the island and minimize the potential for local impacts.

4.5 Aquifer Breach

A major concern with any mining operation is the potential of breaching an aquifer. This situation occurred in a sand and gravel pit near Monroe in Snohomish County in 1993 and impacted adjacent wells by draining an aquifer. None of the planned excavations on this site will breach existing aquifers. There will be local pockets of perched groundwater that will drain during excavation. However, none of the perched groundwater pockets would be considered an aquifer. This is due to their localized limited extent. In addition, it is our experience in similar deposits that these higher saturated zones are seasonal in nature. When breached by an excavation, the detained water readily drains and long-term seepage is not present after the initial drainage.



REFERENCE: THE THOMAS GUIDE, KING COUNTY, WASHINGTON, PAGES 713 AND 714, 1999 EDITION.



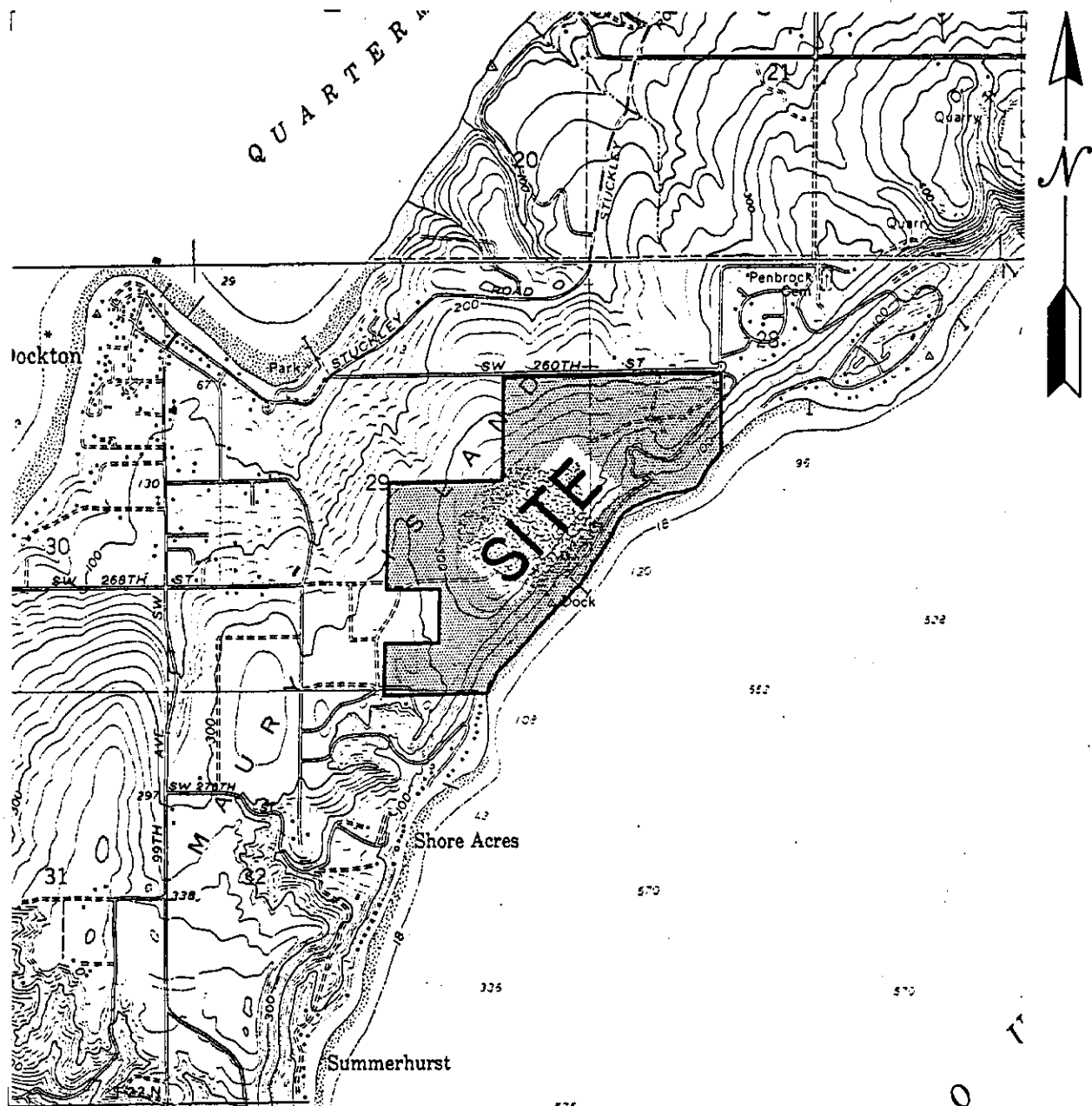
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VICINITY MAP
LONE STAR GRAVEL PIT
MAURY ISLAND
KING COUNTY, WASHINGTON

Proj.No. 4169

Date MAY 1999

Figure 1



APPROXIMATE SCALE 1:24000



CONTOUR INTERVAL (AT SITE): 20 FEET

REFERENCE:

1. USGS QUADRANGLE, VASHON, WASHINGTON, DATED 1949 (PHOTOREVISED 1968).
2. USGS QUADRANGLE, TACOMA (NORTH), WASHINGTON, DATED 1961 (PHOTOREVISED 1981).



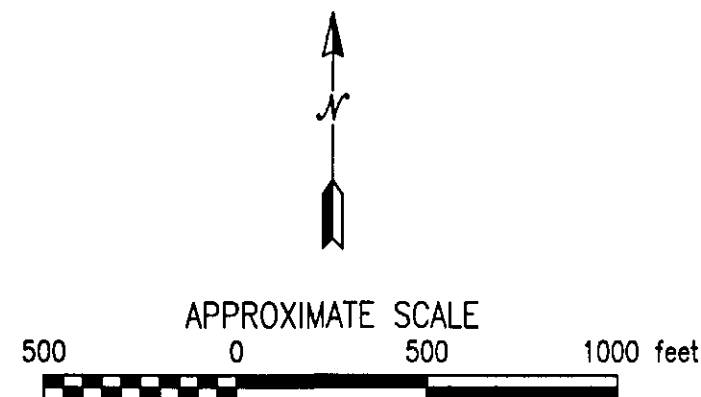
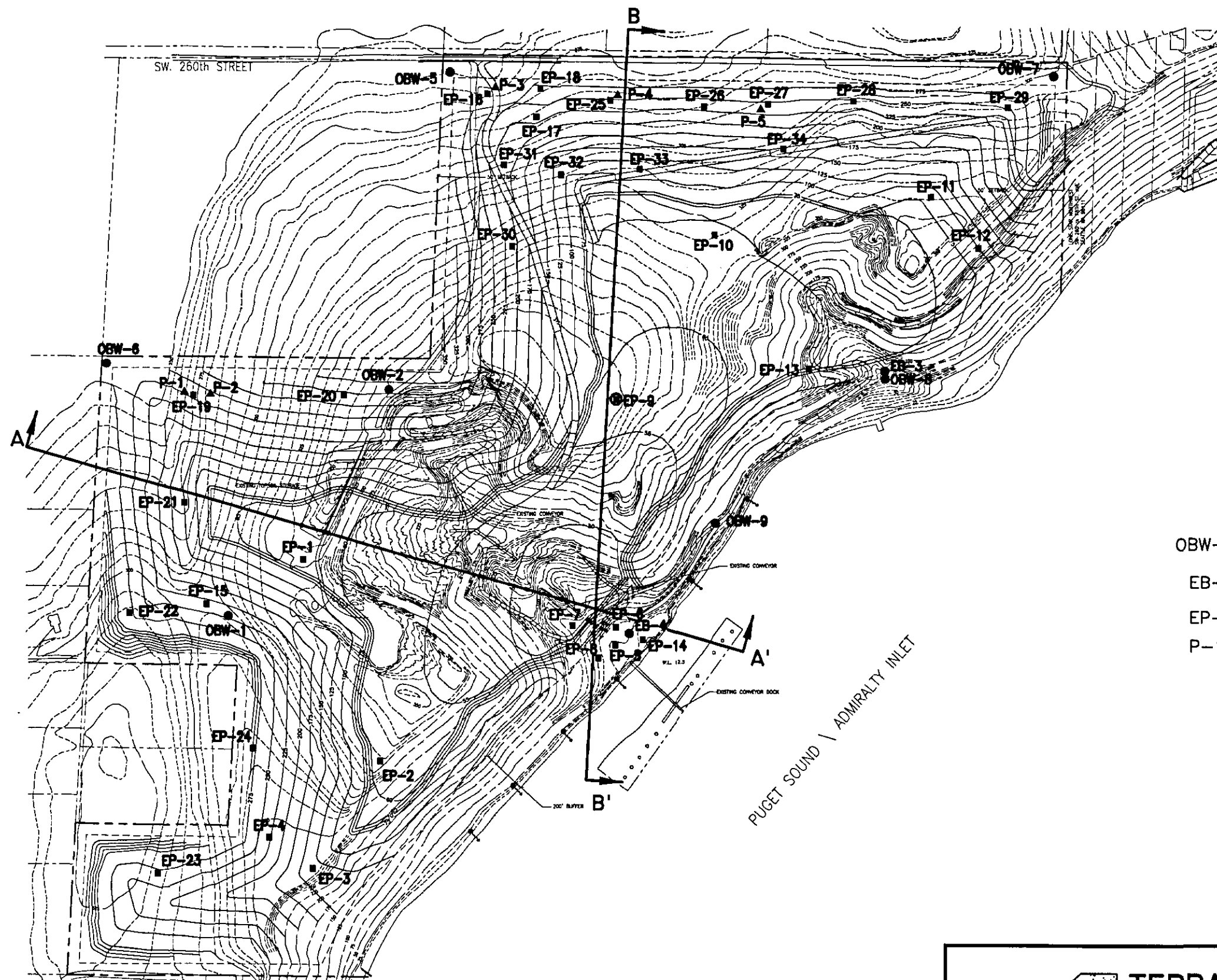
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TOPOGRAPHIC VICINITY MAP
LONE STAR GRAVEL PIT
MAURY ISLAND
KING COUNTY, WASHINGTON

Proj.No. 4169

Date MAY 1999

Figure 2



LEGEND

- OBW-1 ● APPROXIMATE LOCATION OF OBSERVATION WELL
- EB-1 ● APPROXIMATE LOCATION OF EXPLORATION BORING
- EP-1 ■ APPROXIMATE LOCATION OF EXPLORATION PIT
- P-1 ▲ APPROXIMATE LOCATION OF PEIZOMETER
- SCHEMATIC LOCATION OF SPRINGS

REFERENCE:

1. EXPLORATION LOCATION PLAN BY ASSOCIATED EARTH SCIENCES, INC. (AESI).
2. AERIAL MAPPING BY NIES MAPPING GROUP, INC.
3. PROPERTY LINES BY JONES, BASSI & ASSOCIATES, 10/01/70.

Appendix A



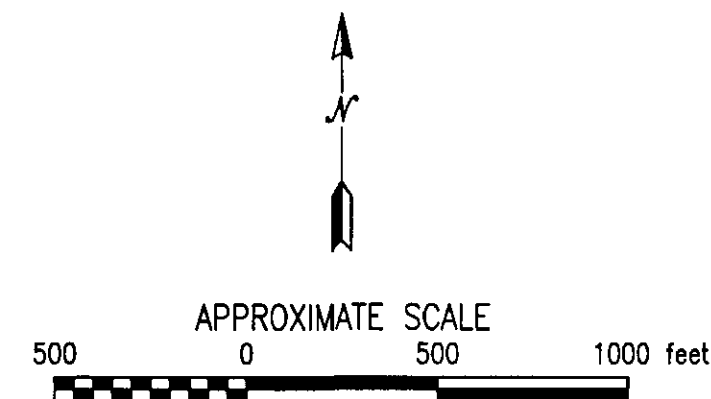
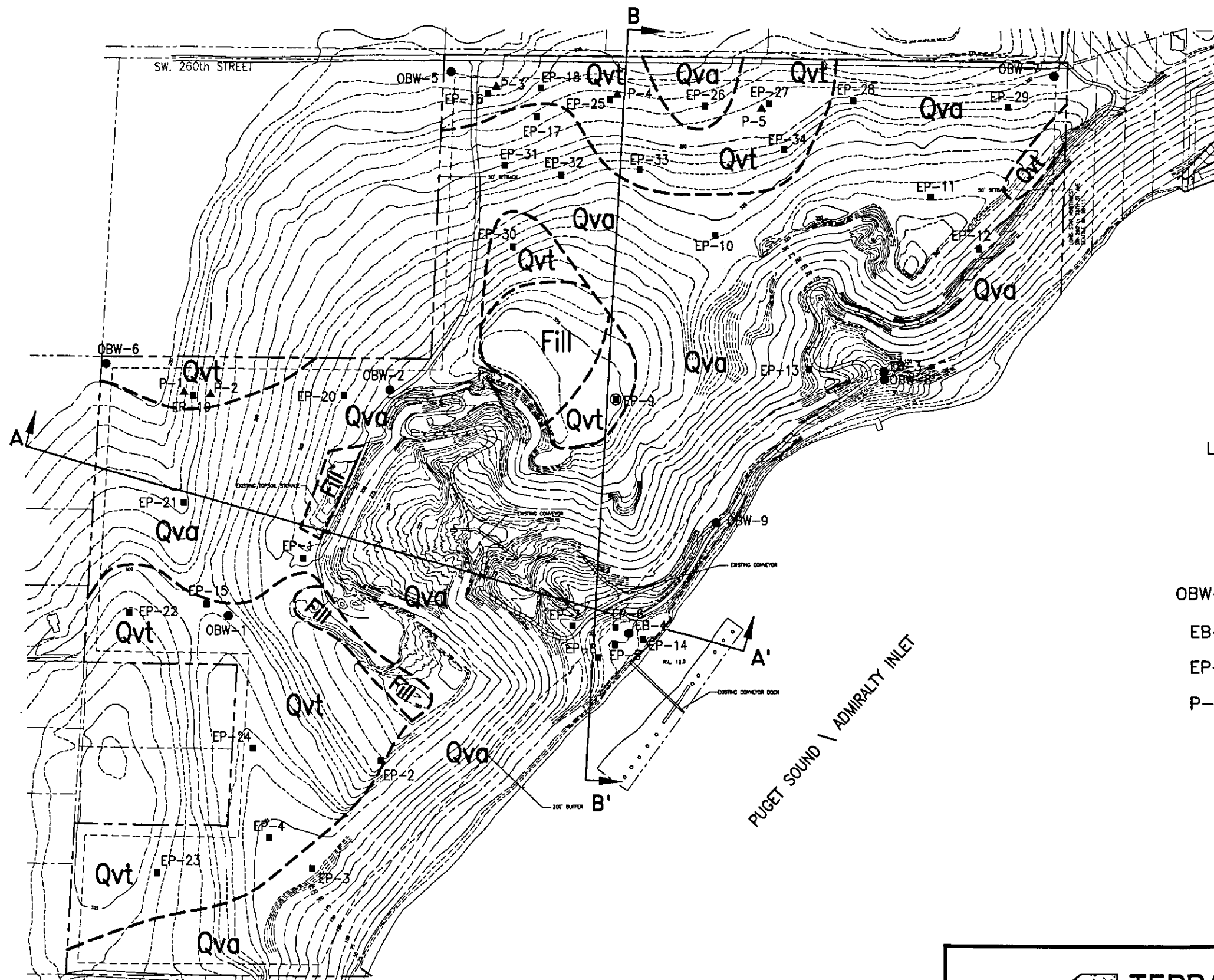
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EXPLORATION LOCATION AND GRADING PLAN
LONE STAR GRAVEL PIT
MAURY ISLAND
KING COUNTY, WASHINGTON

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Date MAY 1999

Figure 3



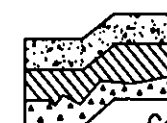
LEGEND

- Fill MATERIAL NOT NATURALLY PLACED
- Qvt VASHON LODGEMENT TILL
- Qva VASHON ADVANCE OUTWASH
- OBW-1 ● APPROXIMATE LOCATION OF OBSERVATION WELL
- EB-1 ● APPROXIMATE LOCATION OF EXPLORATION BORING
- EP-1 ■ APPROXIMATE LOCATION OF EXPLORATION PIT
- P-1 ▲ APPROXIMATE LOCATION OF PEIZOMETER

REFERENCE:

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Appendix A



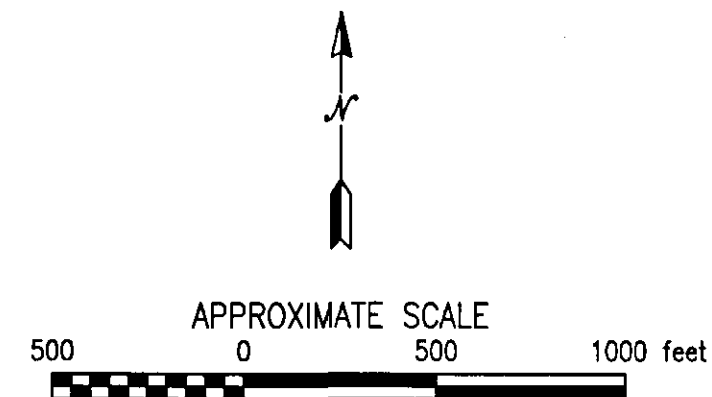
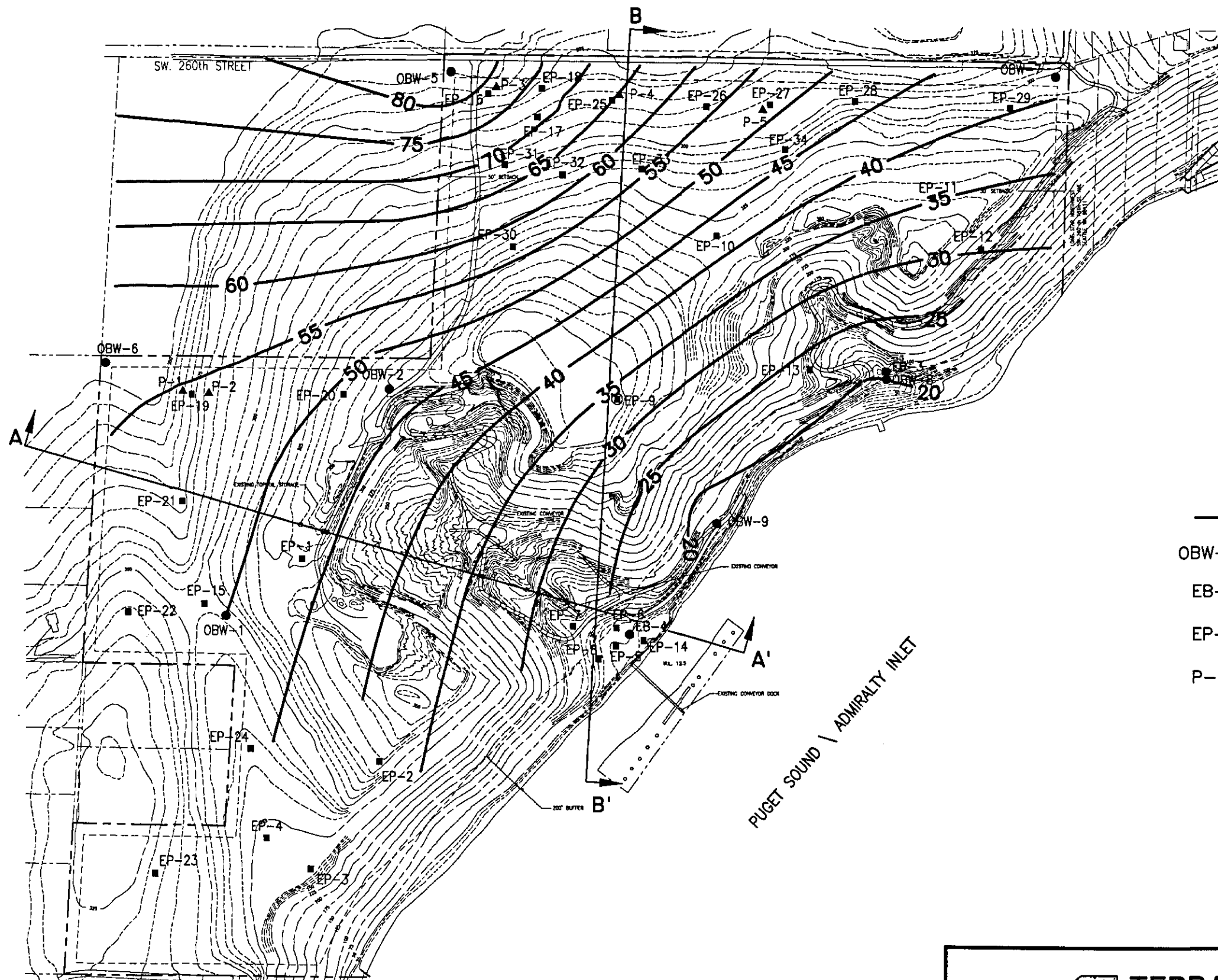
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GEOLOGY MAP
LONE STAR GRAVEL PIT
MAURY ISLAND
KING COUNTY, WASHINGTON

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Date MAY 1999

Figure 4



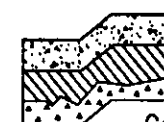
LEGEND

- STATIC WATER LEVEL AS OF 19 FEBRUARY, 1999.
- OBW-1 ● APPROXIMATE LOCATION OF OBSERVATION WELL
- EB-1 ● APPROXIMATE LOCATION OF EXPLORATION BORING
- EP-1 ■ APPROXIMATE LOCATION OF EXPLORATION PIT
- P-1 ▲ APPROXIMATE LOCATION OF PEIZOMETER

REFERENCE:

1. EXPLORATION LOCATION PLAN BY ASSOCIATED EARTH SCIENCES, INC. (AESI).
2. AERIAL MAPPING BY NIES MAPPING GROUP, INC.
3. PROPERTY LINES BY JONES, BASSI & ASSOCIATES, 10/01/70.

Appendix A



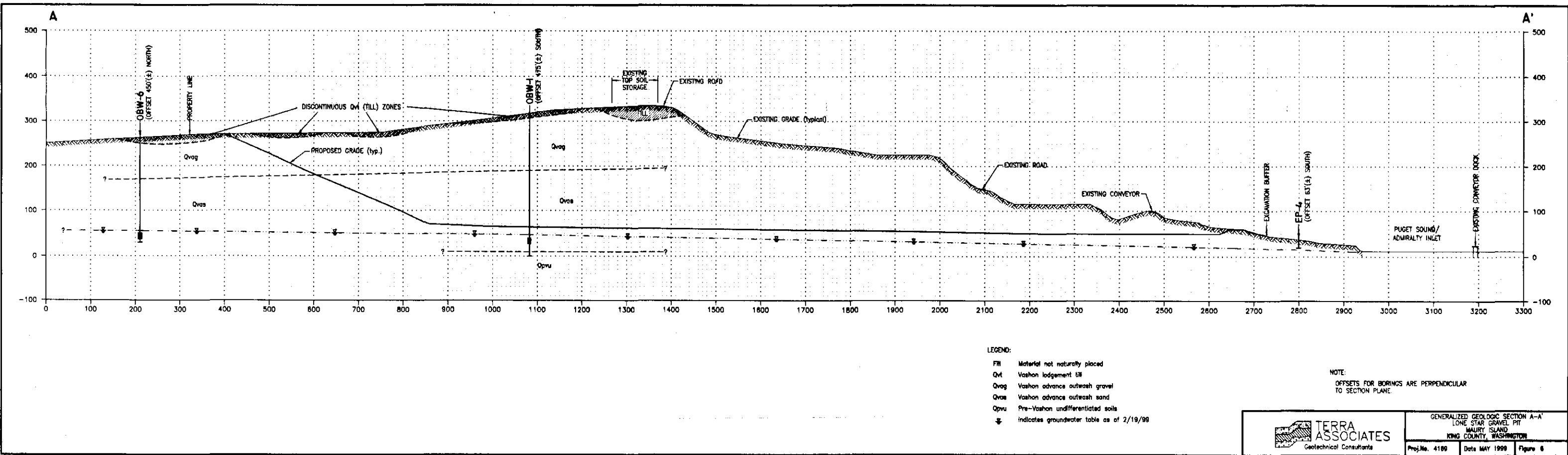
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GROUNDWATER CONTOURS
LONE STAR GRAVEL PIT
MAURY ISLAND
KING COUNTY, WASHINGTON

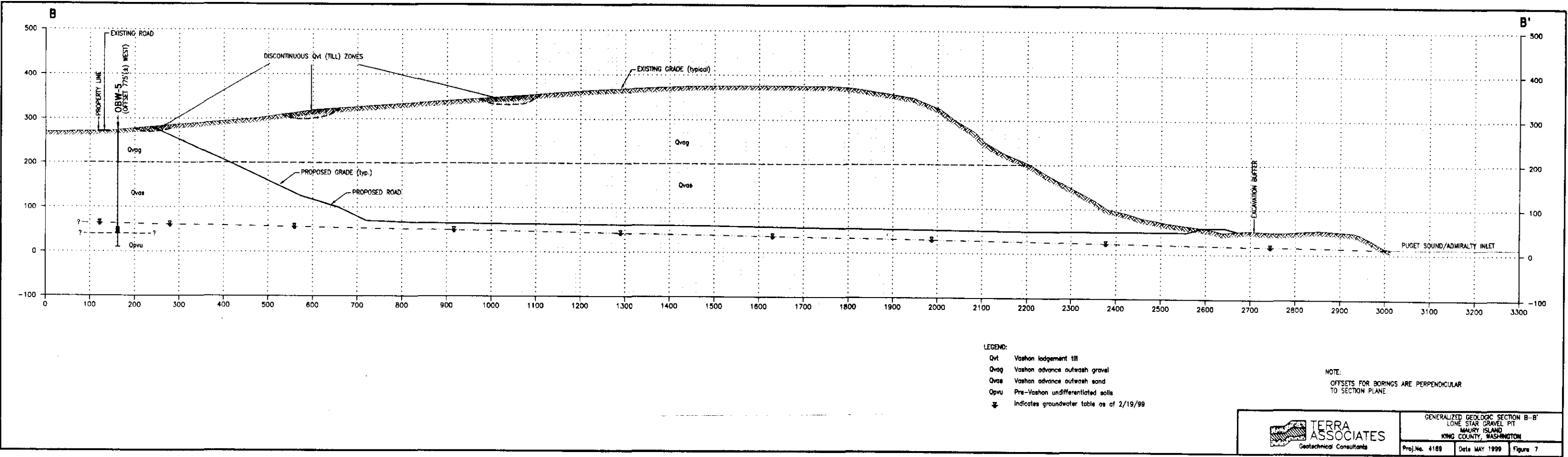
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Date MAY 1999

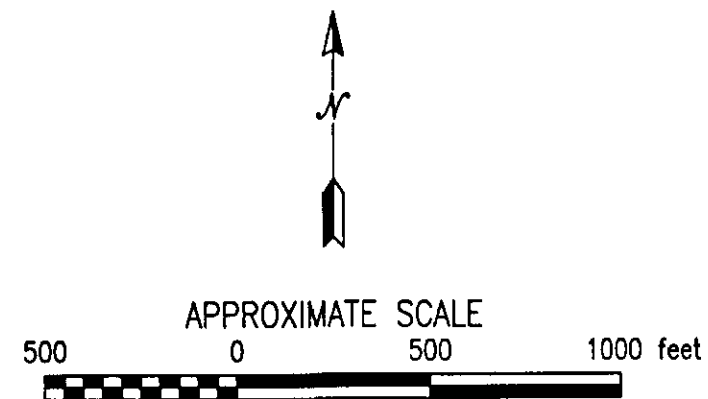
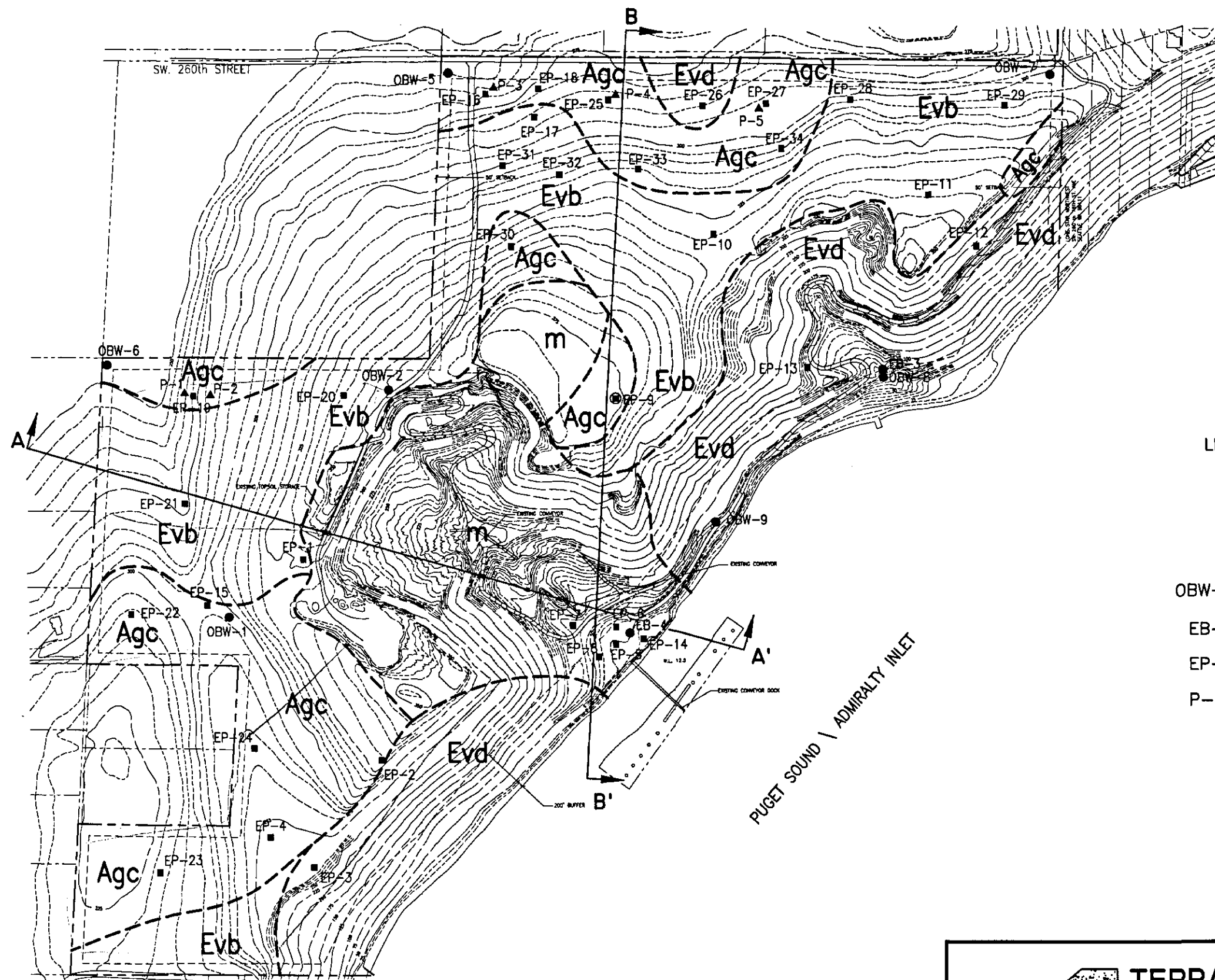
Figure 5



Appendix A



Appendix A



LEGEND

- Evd } EVERETT SOILS
- Agc ALDERWOOD SOILS
- m MODIFIED SOILS

- OBW-1 ● APPROXIMATE LOCATION OF OBSERVATION WELL
- EB-1 ● APPROXIMATE LOCATION OF EXPLORATION BORING
- EP-1 ■ APPROXIMATE LOCATION OF EXPLORATION PIT
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Appendix A



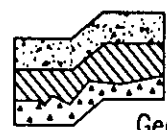
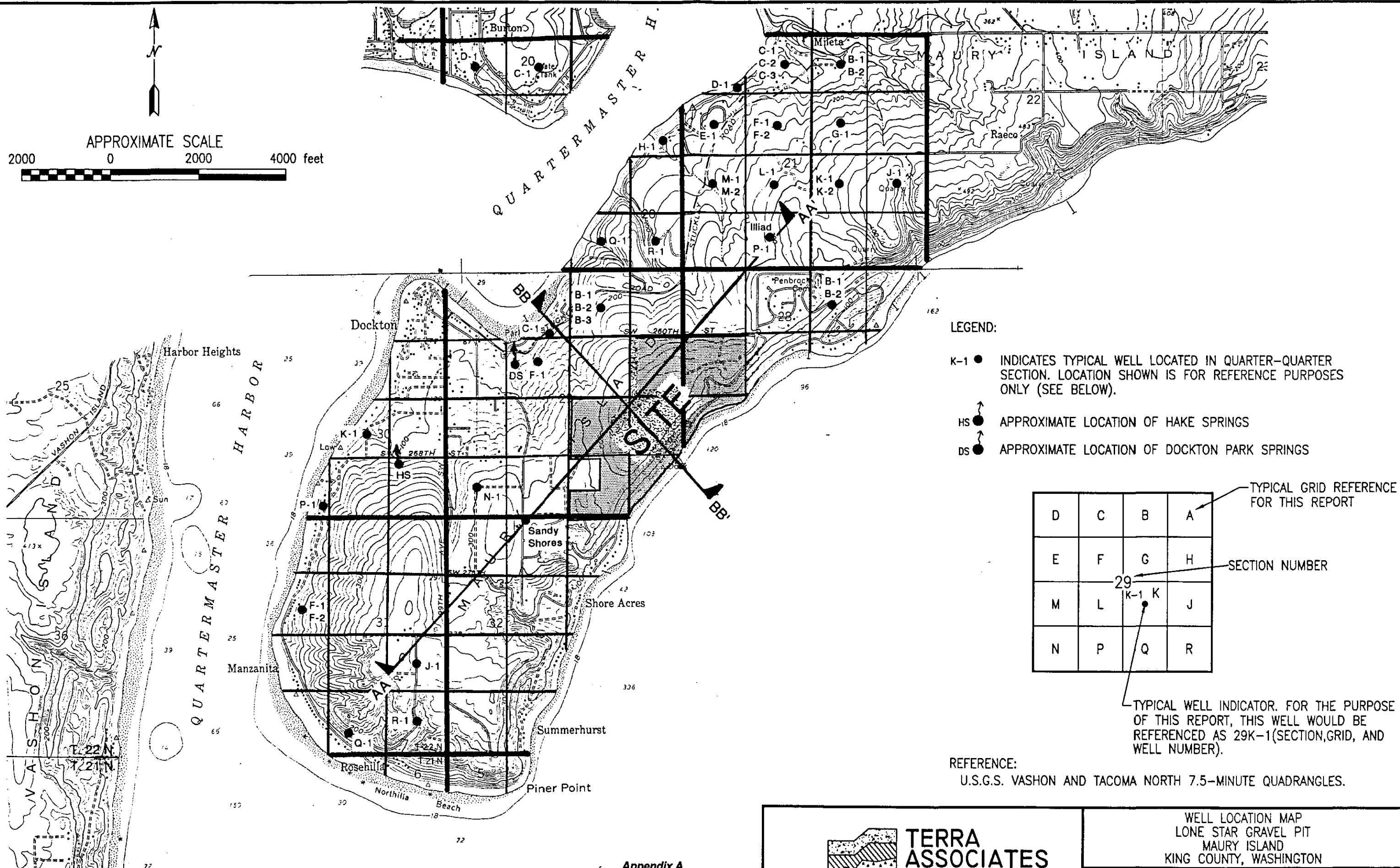
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SOILS MAP
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MAURY ISLAND
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Figure 8



TERRA ASSOCIATES
Geotechnical Consultants

WELL LOCATION MAP
LONE STAR GRAVEL PIT
MAURY ISLAND
KING COUNTY, WASHINGTON

Proj.No. 4169

Date MAY 1999

Figure 9

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GROUNDWATER DISCIPLINE REPORT

**Geology and Groundwater Sections
Lone Star Pit/Maury Island
King County, Washington**

Project No. T-4169

Prepared for:

**Jones and Stokes
Bellevue, Washington**

June 3, 1999

June 3, 1999
Project No. T-4169

Mr. Steve Hall
Jones and Stokes
2820 Northup Way, Suite 100
Bellevue, Washington 98004

Subject: Groundwater Discipline Report
Geology and Groundwater Sections
Lone Star Pit/Maury Island
King County, Washington

Dear Mr. Hall:

As requested, and in accordance with our contract dated November 9, 1998, we have completed the Geology and Groundwater Discipline Report for the Lone Star Site Draft Environmental Impact Statement (DEIS) on Maury Island. After reviewing the existing information, we recommended additional exploration work be done to assess existing conditions. We developed a scope of work to obtain additional data, which was reviewed and implemented by the proponent's consultant, Associated Earth Sciences, Inc. The results of this additional work were included in our analysis and are summarized in the attached narrative and illustrations. Development of the mine as proposed should have no significant adverse impact to the adjacent groundwater wells, provided the mitigations contained in this report are incorporated into site development plans.

We trust the information presented is sufficient for your current needs. If you have any questions or require additional information, please call.

Sincerely yours,
TERRA ASSOCIATES, INC.

Charles R. Lie
Senior Engineering Geologist

Theodore J. Schepper, P.E.
Principal Engineer

APPENDIX A

REFERENCES

REFERENCES

Associated Earth Sciences 1998. Soils, Geology, Geologic Hazards and Groundwater Report, Existing Conditions, Impacts and Mitigations, Maury Island Pit. Prepared for Lone Star Northwest, March 27, 1998, revised April 27, 1998.

Associated Earth Sciences 1999a. Draft Addendum, Geology, and Groundwater Report, Maury Island Pit. Prepared for Lone Star Northwest, March 3, 1999.

Associated Earth Sciences 1999b. Technical Memorandum, Maury Island Pit. Prepared for Lone Star Northwest, March 16, 1999.

AESI 1999c. E-mail memo from Homer Welborn, April 9, 1999.

Bauer, H. H. et al, 1997, Recharge from Precipitation in Three Small Catchments in the Puget Sound Lowland, Washington, United States Geologic Survey 1997.

Booth, D.B. 1991. Geologic Map of Vashon and Maury Island, King County, Washington with text to accompany map MF2161 U. S. Department of the Interior, U.S. Geologic Survey, Map Distribution Center, Denver, Colorado.

Carr, J.R. Associates 1983. Vashon/Maury Island Water Resources Study, Seattle, Washington, December 1, 1983.

ESM 1996. Reclamation Permit for Lone Star Northwest's Maury Island's Sand and Gravel Pit prepared for Lone Star Northwest, November 1996, revised January 1997, second revision April 1998.

Ritzi, Robert 1983. The Hydrologic Setting and Water Resources of Vashon and Maury Islands, King County Washington. Thesis of Master of Science fulfillment, Wright State University, June 1983.

Rongey/Associates, Hydrology 1998. Hydrogeological Review Maury Island Pit prepared for Gold Beach Water Company, May 1998.

Soil Conservation Service, 1973, Soil Survey, King County Area, Washington. United States Department of Agriculture, Soils Conservation Service, November 1973.

Vashon-Maury Island Ground Water Advisory Committee 1998. Vashon-Maury Island Groundwater Management Plan and Supplement, Area Characterization. King County Department of Natural Resources 1998.

Washington State Department of Ecology, central files, well logs for sections 20, 21, 22, 28, 29, 30, 31, and 32 Township 22N, Range 3E.

APPENDIX B

WELL LOGS

APPENDIX C

STATIC WATER LEVEL SUMMARY